

**MAXIM**

# **USB Current-Limited Switch in Pin-Compatible Package**

**MAX1607**

## **General Description**

The MAX1607 is a current-limited 60mΩ switch with built-in fault blanking. Its accurate, preset 0.7A to 1.0A current limit makes it ideal for USB applications. Its low quiescent supply current (14µA) and standby current (1µA) conserve battery power in portable applications. The MAX1607 operates with inputs from +2.7V to +5.5V, making it ideal for both 3V and 5V systems.

An overcurrent signal ( $\overline{OC}$ ) notifies the microprocessor that the internal current limit has been reached. A 10ms overcurrent-blanking feature allows momentary faults (such as those caused when hot-swapping into a capacitive load) to be ignored, thus preventing false alarms to the host system. This blanking also prevents an  $\overline{OC}$  signal from being issued when the device is powering up.

The MAX1607 has several safety features to ensure that the USB port is protected. Built-in thermal-overload protection limits power dissipation and junction temperature. The device also has accurate internal current-limiting circuitry to protect the input supply against overload.

The MAX1607 is a pin-compatible upgrade to Texas Instruments' TPS2014, TPS2015, and TPS2041 for USB applications. The same die is available in a space-saving 10-pin µMAX package (MAX1693) and can be used for next-generation designs. The MAX1694 is similar to the MAX1693, but it has a built-in latch that turns off the power switch in case of a long-term short-circuit condition.

## **Applications**

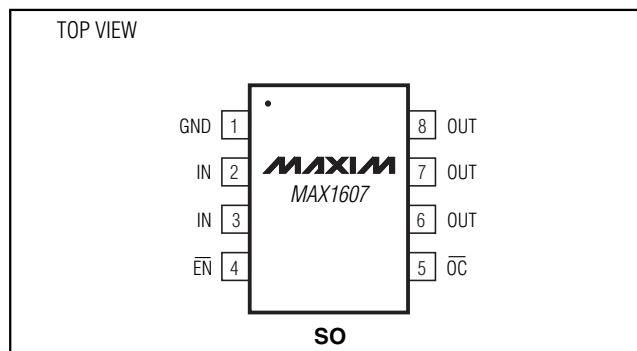
Notebook Computers

USB Ports

USB Hubs

Docking Stations

## **Pin Configuration**

**MAXIM**

For price, delivery, and to place orders, please contact Maxim Distribution at 1-888-629-4642, or visit Maxim's website at [www.maxim-ic.com](http://www.maxim-ic.com).

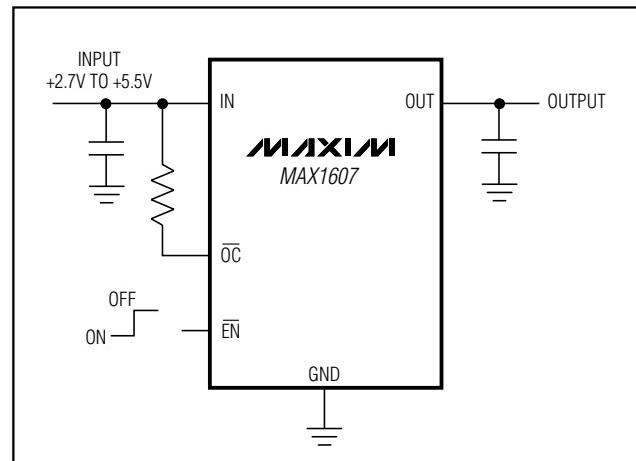
## **Features**

- ◆ Pin Compatible with TPS2014, TPS2015, and TPS2041
- ◆ Accurate Current Limit (0.7A min, 1.0A max)
- ◆ Guaranteed 0.75A Short-Circuit Protection
- ◆ 10ms Internal  $\overline{OC}$  Blanking Timeout
- ◆ No Overcurrent ( $\overline{OC}$ ) Signal During Power-Up
- ◆ 125mΩ max High-Side MOSFET
- ◆ 500mA Continuous Current
- ◆ Short-Circuit and Thermal Protection with Overcurrent Logic Output
- ◆ 1ms Start-Up Time
- ◆ Undervoltage Lockout
- ◆ 14µA Quiescent Supply Current
- ◆ 1µA max Standby Supply Current
- ◆ +2.7V to +5.5V Supply Range
- ◆ UL Approved – #E211935

## **Ordering Information**

PART	TEMP. RANGE	PIN-PACKAGE
MAX1607ESA	-40°C to +85°C	8 SO

## **Typical Operating Circuit**



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# USB Current-Limited Switch in Pin-Compatible Package

## ABSOLUTE MAXIMUM RATINGS

IN, $\overline{EN}$ , $\overline{OC}$ to GND .....	-0.3 to +6V
OUT to GND .....	-0.3V to ( $V_{IN}$ + 0.3V)
Maximum Switch Current.....	1.2A (internally limited)
OUT Short-Circuit to GND .....	Continuous

Continuous Power Dissipation ( $T_A = +70^\circ C$ )	
8-Pin SO (derate 5.88mW/ $^\circ C$ above $+70^\circ C$ ) .....	471mW
Operating Temperature Range (extended) .....	-40°C to +85°C
Storage Temperature Range .....	-65°C to +150°C
Lead Temperature (soldering, 10s) .....	+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

( $V_{IN} = +5V$ ,  $T_A = 0^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
<b>OPERATING CONDITION</b>							
Input Voltage	$V_{IN}$			2.7	5.5	5.5	V
<b>POWER SWITCH</b>							
Switch Static Drain-Source On-State Resistance	$R_{DS(ON)}$	$T_A = +25^\circ C$	$V_{IN} = 4.4V$ to 5.5V	60	90		$m\Omega$
		$T_A = 0^\circ C$ to $+85^\circ C$	$V_{IN} = 4.4V$ to 5.5V		125		
			$V_{IN} = 3V$	72	150		
Switch Turn-On Time	$t_{ON}$	$I_{LOAD} = 400mA$		80	200		$\mu s$
Switch Turn-Off Time	$t_{OFF}$	$I_{LOAD} = 400mA$		3	6	20	$\mu s$
<b>ENABLE INPUT (<math>\overline{EN}</math>)</b>							
$\overline{EN}$ High-Level Input Voltage	$V_{IH}$	$V_{IN} = 2.7V$ to 3.6V		2.0			V
		$V_{IN} = 3.7V$ to 5.5V		2.4			
$\overline{EN}$ Low-Level Input Voltage	$V_{IL}$	$V_{IN} = 2.7V$ to 5.5V			0.8	0.8	V
$\overline{EN}$ Input Current		$V_{\overline{EN}} = V_{IN}$ or GND		-1	1	1	$\mu A$
Start-Up Time		$V_{IN} = 5V$ , $C_{OUT} = 150\mu F$ from $\overline{EN}$ driven low to 50% full $V_{OUT}$		1			ms
<b>CURRENT LIMIT</b>							
Overload Output Current	$I_{LIMIT}$	Force $V_{OUT}$ to 4.5V		700	850	1000	mA
Short-Circuit Output Current	$I_{SC}$	OUT shorted to GND		500	700	700	mA
<b>SUPPLY CURRENT</b>							
Supply Current, Low-Level Input		$V_{\overline{EN}} = V_{IN} = V_{OUT} = 5.5V$		0.001	1	1	$\mu A$
Supply Current, High-Level Input	$I_Q$	$V_{\overline{EN}} = GND$ , $I_{OUT} = 0$	Timer not running	14	25		$\mu A$
			Timer running	35			
Supply Leakage Current		$V_{\overline{EN}} = V_{IN} = 5.5V$ , $V_{OUT} = GND$	$T_A = +25^\circ C$	0.01	2		$\mu A$
			$T_A = 0^\circ C$ to $+85^\circ C$		15		
<b>UNDERVOLTAGE LOCKOUT</b>							
Undervoltage Lockout	$UVLO$	Rising edge, 100mV hysteresis		2.0	2.4	2.6	V
<b>OVERCURRENT (<math>\overline{OC}</math>)</b>							
$\overline{OC}$ Output Low Voltage	$V_{OL}$	$I_{SINK} = 1mA$ , $V_{IN} = 3V$			0.4	0.4	V
$\overline{OC}$ Off-State Current		$V_{IN} = V_{\overline{OC}} = 5V$			1	1	$\mu A$
$\overline{OC}$ Blanking Timeout Period	$t_{BL}$	From overcurrent condition to $\overline{OC}$ assertion		7	10	13	ms
<b>THERMAL SHUTDOWN</b>							
Thermal Shutdown Threshold				+	165		$^\circ C$

# **USB Current-Limited Switch in Pin-Compatible Package**

## **ELECTRICAL CHARACTERISTICS**

( $V_{IN} = +5V$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>OPERATING CONDITION</b>						
Input Voltage	$V_{IN}$		3.0	5.5	V	
<b>POWER SWITCH</b>						
Switch Static Drain-Source On-State Resistance	$R_{DS(ON)}$	$V_{IN} = 4.4V$ to $5.5V$	125	$m\Omega$		
		$V_{IN} = 3V$	150			
Switch Turn-On Time	$t_{ON}$	$I_{LOAD} = 400mA$		200	$\mu s$	
Switch Turn-Off Time	$t_{OFF}$	$I_{LOAD} = 400mA$	1	20	$\mu s$	
<b>ENABLE INPUT (<math>\bar{EN}</math>)</b>						
$\bar{EN}$ High-Level Input Voltage	$V_{IH}$	$V_{IN} = 3.0V$ to $3.6V$	2.0	$V$		
		$V_{IN} = 3.7V$ to $5.5V$	2.4			
$\bar{EN}$ Low-Level Input Voltage	$V_{IL}$	$V_{IN} = 3.0V$ to $5.5V$		0.8	$V$	
$\bar{EN}$ Input Current		$\bar{V}_{EN} = V_{IN}$ or GND	-1	1	$\mu A$	
<b>CURRENT LIMIT</b>						
Overload Output Current	$I_{LIMIT}$	Force $V_{OUT}$ to $4.5V$	640	1060	mA	
Short-Circuit Output Current	$I_{SC}$	OUT shorted to GND		750	mA	
<b>SUPPLY CURRENT</b>						
Supply Current, Low-Level Input		$\bar{V}_{EN} = V_{IN} = V_{OUT} = 5.5V$		2	$\mu A$	
Supply Current, High-Level Input	$I_Q$	$\bar{V}_{EN} = GND$ , $I_{OUT} = 0$ , timer not running		25	$\mu A$	
Supply Leakage Current		$\bar{V}_{EN} = V_{IN} = 5.5V$ , $V_{OUT} = GND$		15	$\mu A$	
<b>UNDERVOLTAGE LOCKOUT</b>						
Undervoltage Lockout	$UVLO$	Rising edge, 100mV hysteresis	2.0	2.9	V	
<b>OVERTCURRENT (<math>\bar{OC}</math>)</b>						
$\bar{OC}$ Output Low Voltage	$V_{OL}$	$I_{SINK} = 1mA$ , $V_{IN} = 3V$		0.4	V	
$\bar{OC}$ Off-State Current		$V_{IN} = V_{OC} = 5V$		1	$\mu A$	
$\bar{OC}$ Blanking Timeout Period	$t_{BL}$	From overcurrent condition to $\bar{OC}$ assertion	6	14	ms	

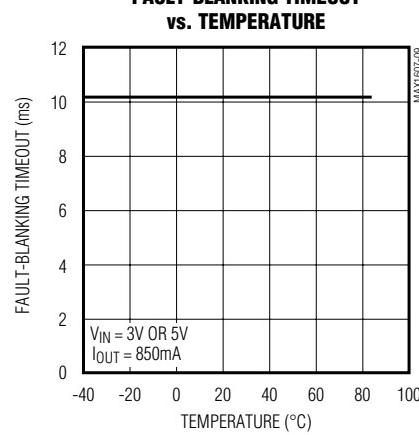
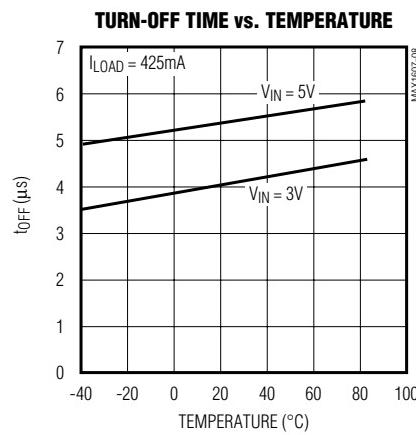
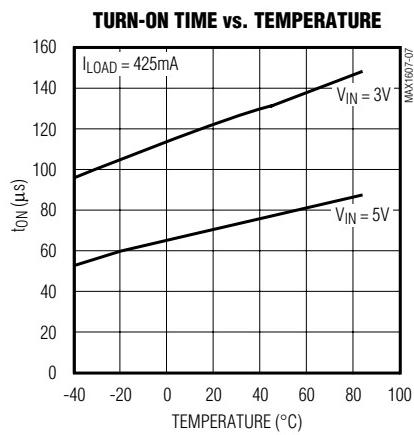
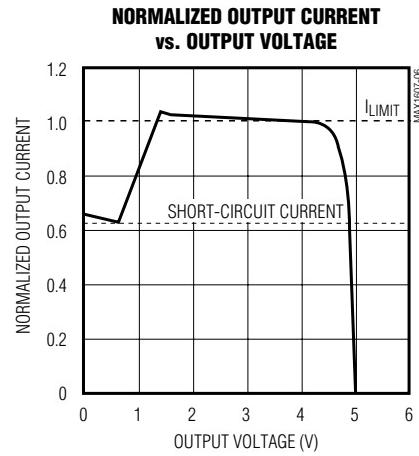
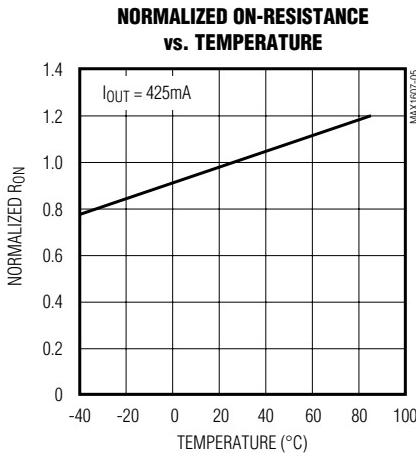
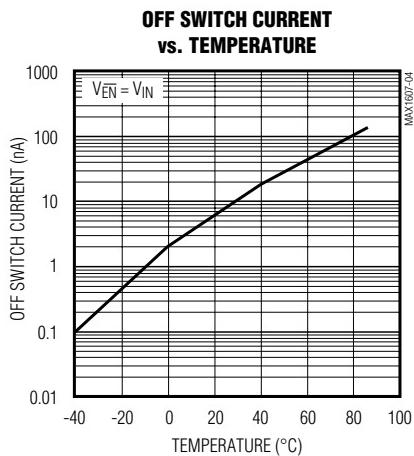
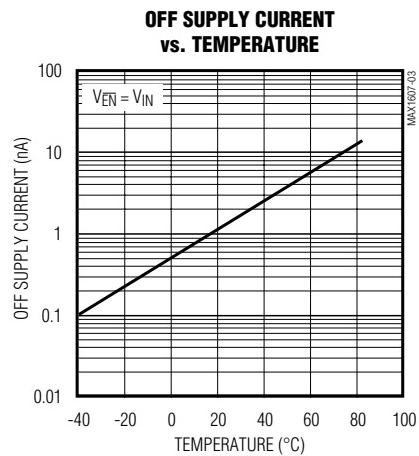
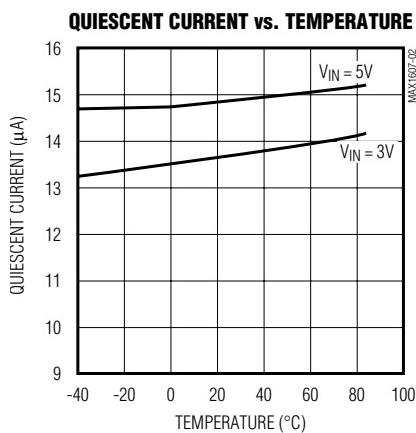
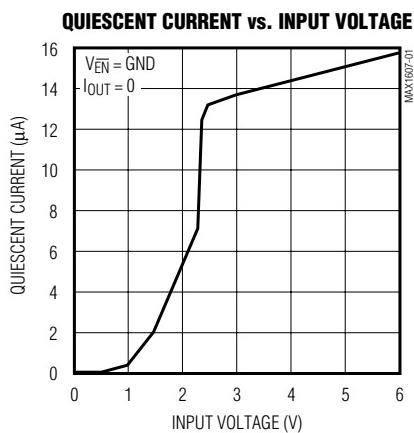
**Note 1:** Specifications to  $-40^\circ C$  are guaranteed by design, not production tested.

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## Typical Operating Characteristics

( $V_{IN} = +5V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



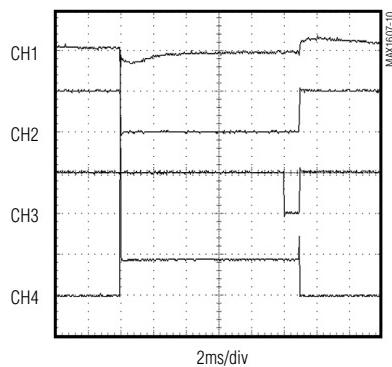
# USB Current-Limited Switch in Pin-Compatible Package

## Typical Operating Characteristics (continued)

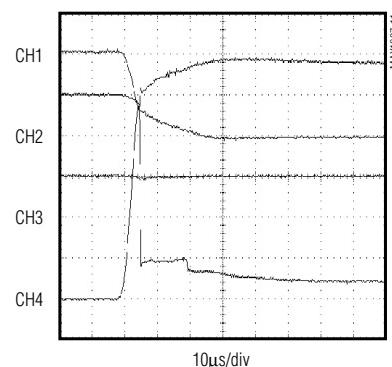
( $V_{IN} = +5V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

**MAX1607**

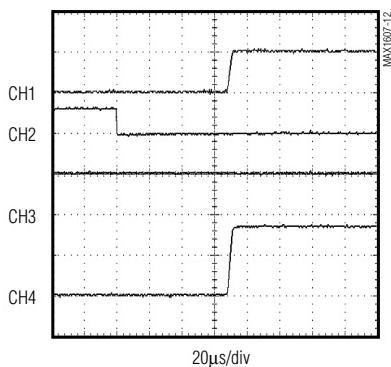
CURRENT-LIMIT AND  $\bar{O}C$  RESPONSE



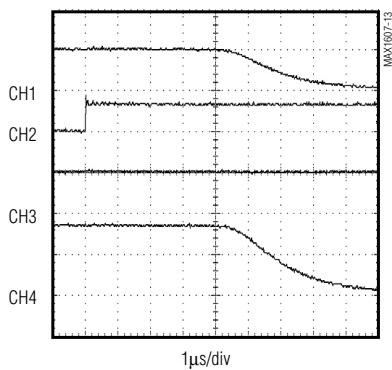
CURRENT-LIMIT RESPONSE



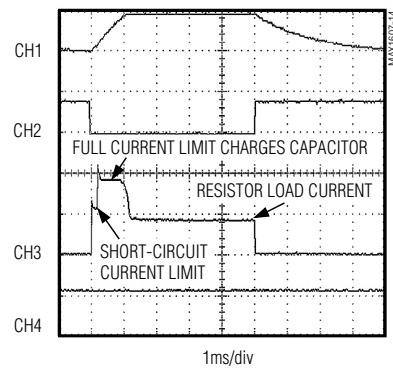
SWITCH TURN-ON TIME



SWITCH TURN-OFF TIME



START-UP TIME  
(TYPICAL USB APPLICATION)



# USB Current-Limited Switch in Pin-Compatible Package

## Pin Description

PIN	NAME	FUNCTION
1	GND	Ground
2, 3	IN	Input. P-channel MOSFET source—connect all IN pins together and bypass with a 1 $\mu$ F capacitor to ground.
4	$\overline{EN}$	Active-Low Switch Enable Input. A logic low turns on the switch.
5	$\overline{OC}$	Overcurrent-Indicator Output. This open-drain output goes low when the device is in thermal shutdown or undervoltage lockout, or during a sustained ( $>10\text{ms}$ ) current-limit condition.
6, 7, 8	OUT	Switch Output. P-channel MOSFET drain—connect all OUT pins together and bypass with a 0.1 $\mu$ F capacitor to ground.

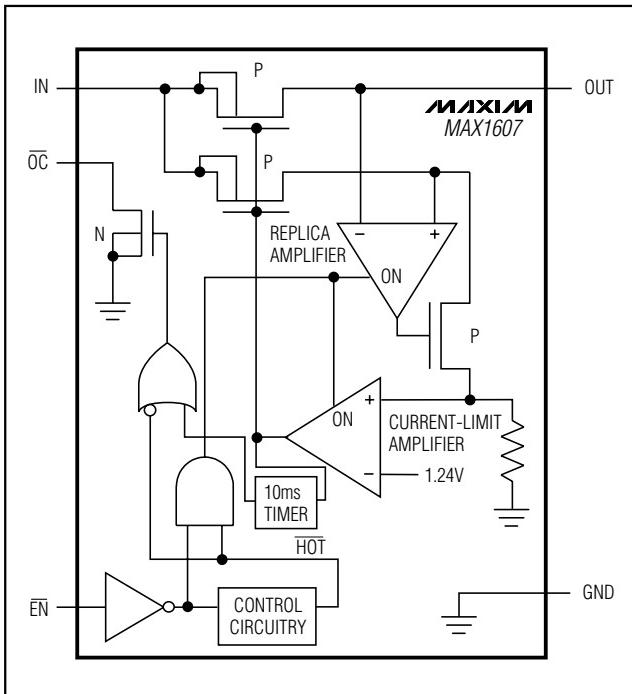


Figure 1. Functional Diagram

## Detailed Description

The MAX1607 P-channel MOSFET power switch limits output current to 0.7A min and 1.0A max. When the output current is increased beyond the current limit (I<sub>LIMIT</sub>), the current also increases through the replica switch (I<sub>OUT</sub> / 6500). The current-limit error amplifier compares the voltage to the internal 1.24V reference and regulates the current back to the I<sub>LIMIT</sub> (Figure 1).

These switches are not bidirectional; therefore, the input voltage must be higher than the output voltage.

## Continuous Short-Circuit Protection

The MAX1607 is a short-circuit-protected switch. In the event of an output short-circuit condition, the current through the switch is foldback-current-limited to 500mA continuous.

## Thermal Shutdown

The MAX1607 has a thermal shutdown feature. The switch turns off and the  $\overline{OC}$  output goes low immediately (no overcurrent blanking) when the junction temperature exceeds +165°C. When the MAX1607 cools 20°C, the switch turns back on. If the fault short-circuit condition is not removed, the switch will cycle on and off, resulting in a pulsed output.

## $\overline{OC}$ Indicator

The MAX1607 provides an overcurrent output ( $\overline{OC}$ ). A 100k $\Omega$  pull-up resistor from  $\overline{OC}$  to IN provides a logic control signal. This open-drain output goes low when any of the following conditions occur:

- The input voltage is below the 2.4V undervoltage-lockout (UVLO) threshold.
- The die temperature exceeds the thermal shutdown temperature limit of +165°C.
- The device is in current limit for greater than 10ms.

## $\overline{OC}$ Blanking

The MAX1607 features 10ms overcurrent blanking. Blanking allows brief current-limit faults, including momentary short-circuit faults that occur when hot-swapping a capacitive load, and also ensures that no  $\overline{OC}$  is issued during power-up. When a load transient causes the device to enter current limit, an internal counter starts. If the load fault persists beyond the 10ms overcurrent-blanking timeout, the  $\overline{OC}$  output asserts low. Ensure that the MAX1607 input is adequately bypassed to prevent input glitches from triggering spurious  $\overline{OC}$  outputs. Input voltage glitches less

# USB Current-Limited Switch in Pin-Compatible Package

than 150mV will not cause a spurious  $\overline{OC}$  output. Load-transient faults less than 10ms (typ) will not cause an  $\overline{OC}$  output assertion.

Only current-limit faults are blanked. Die overtemperature faults and input voltage drops below the UVLO threshold will cause an immediate  $\overline{OC}$  output.

## Applications Information

### Input Capacitor

To limit the input voltage drop during momentary output short-circuit conditions, connect a capacitor from IN to GND. A 1 $\mu$ F ceramic capacitor will be adequate for most applications; however, higher capacitor values will further reduce the voltage drop at the input (Figure 2).

### Output Capacitor

Connect a 0.1 $\mu$ F capacitor from OUT to GND. This capacitor helps to prevent inductive parasitics from pulling OUT negative during turn-off.

### Layout and Thermal Dissipation

**Important:** Optimize the switch response time to output short-circuit conditions by keeping all traces as short as possible to reduce the effect of undesirable parasitic inductance. Place input and output capacitors as close as possible to the device (no more than 5mm away). All IN and OUT pins must be connected with short traces to the power bus. Wide power-bus planes will provide superior heat dissipation through the MAX1607's IN and OUT pins.

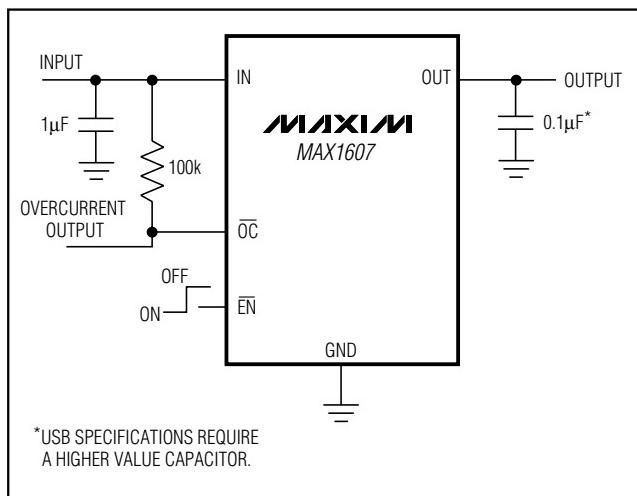


Figure 2. Typical Application Circuit

Under normal operating conditions, the package can dissipate and channel heat away. Calculate the maximum power dissipation as follows:

$$P = (I_{LIMIT})^2 \times R_{ON}$$

where  $I_{LIMIT}$  is the preset current limit (1.0A max) and  $R_{ON}$  is the on-resistance of the switch (125m $\Omega$  max).

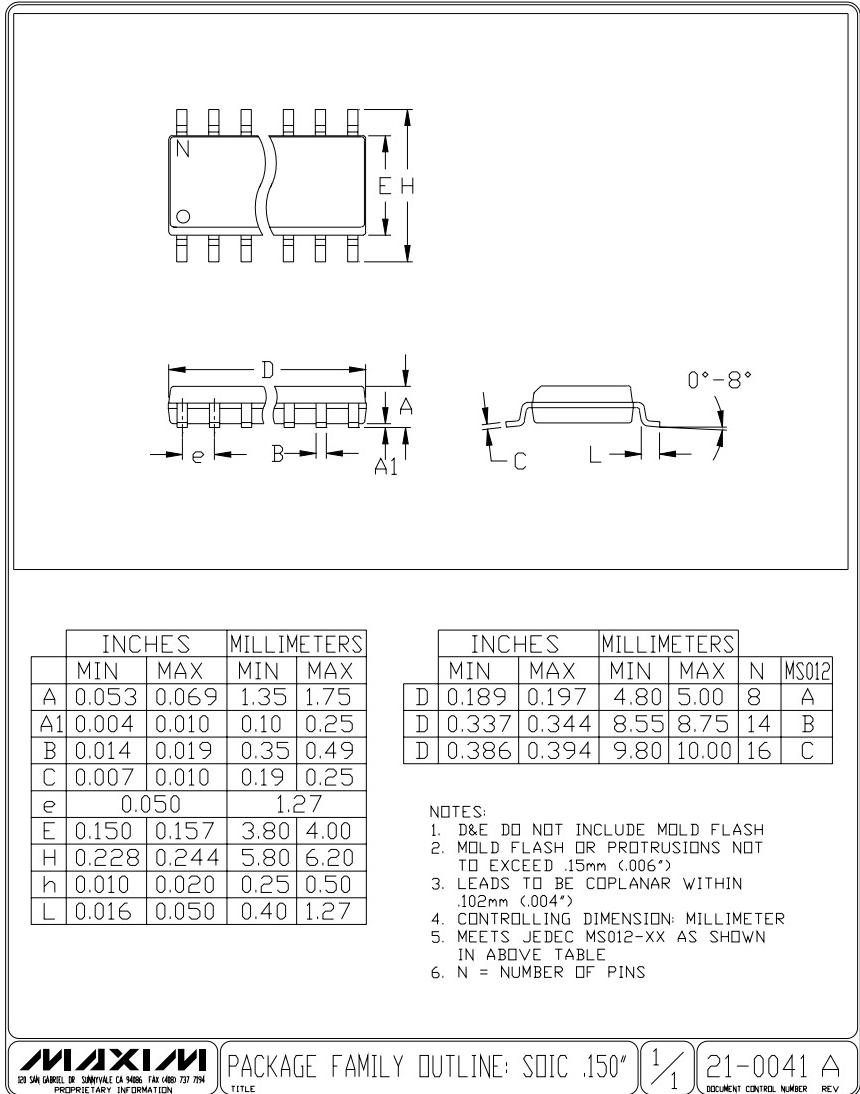
When the output is short circuited, foldback-current limiting activates and the voltage drop across the switch equals the input supply. The power dissipated across the switch increases, as does the die temperature. If the fault condition is not removed, the thermal-overload-protection circuitry activates (see *Thermal Shutdown* section). Wide power-bus planes connected to IN and OUT and a ground plane in contact with the device will help dissipate additional heat.

## Chip Information

TRANSISTOR COUNT: 715

# USB Current-Limited Switch in Pin-Compatible Package

## Package Information



Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

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